

Hybrid Pulsators — Pulsating Stars with Multiple Identities *

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Abstract We have carried out a statistic survey on the pulsating variable stars with multiple identities. These stars were identified to exhibit two types of pulsation or multiple light variability types in the literature, and are usually called hybrid pulsators. We extracted the hybrid information based on the Simbad database. Actually, all the variables with multiple identities are retrieved. The survey covers various pulsating stars across the Hertzsprung-Russell diagram. We aim at giving a clue in selecting interesting targets for further observation. Hybrid pulsators are excellent targets for asteroseismology. An important implication of such stars is their potential in advancing the theories of both stellar evolution and pulsation. By presenting the statistics, we address the open questions and prospects regarding current status of hybrid pulsation studies.

Key words: stars: oscillation (pulsation) — stars: binaries: eclipsing: Algol — stars: variables: β Cephei, Cepheids, δ Scuti, γ Doradus, Red Giant Branch, RR Lyrae, sdBV, SPB, pulsating White Dwarf, CV, Wolf-Rayet, post-AGB

1 MOTIVATION

Pulsating stars are a kind of intrinsic variable stars, which show periodic brightness/luminosity fluctuations due to gradient opacities on the outer layers and in deep interior of the stars. Different types of pulsating stars are distinguished by their periods of pulsation and the shapes of their light curves. They are located in different instability strips on the Hertzsprung-Russell diagram (see e.g. Fig 1). The stars in different areas have distinctly different physical properties and are in different evolutionary stages of their life. These instability domains are not necessarily distinct, but may be overlapped. Stars having two different sets of pulsation spectra excited simultaneously may therefore exist within overlapping instability strips. When a pulsating variable star exhibits two types of pulsation, or it is identified to be multiple variability types, we usually call it ‘a hybrid pulsator’.

Stellar pulsation (frequency) carries valuable information on the physical condition within the star. According to pulsational theory, oscillations must be trapped in some part of the stellar interior, i.e. different mode types of pulsation are trapped in different regions in the star’s interior, and are driven by different excitation mechanisms. Low-order non-radial modes have mixed character: acoustic-type in the envelope and gravity-type in the deep radiative interior. Three types of oscillation have been detected widely in stars: (1) the stochastic oscillations generated by convection near stellar surface are observed in the Sun and solar-like stars; (2) pressure modes (p modes) refer to the outer convection layers of a star; while (3) gravity modes (g modes) penetrate deep into the radiative zone. Hybrid pulsators having two mode types such as p - and g -modes simultaneously are of particular interest since the two mode types probe different regions within the star. A hybrid pulsator is thus much interesting

* Web version at <http://www.chjaa.org/COB/hybrid/>.

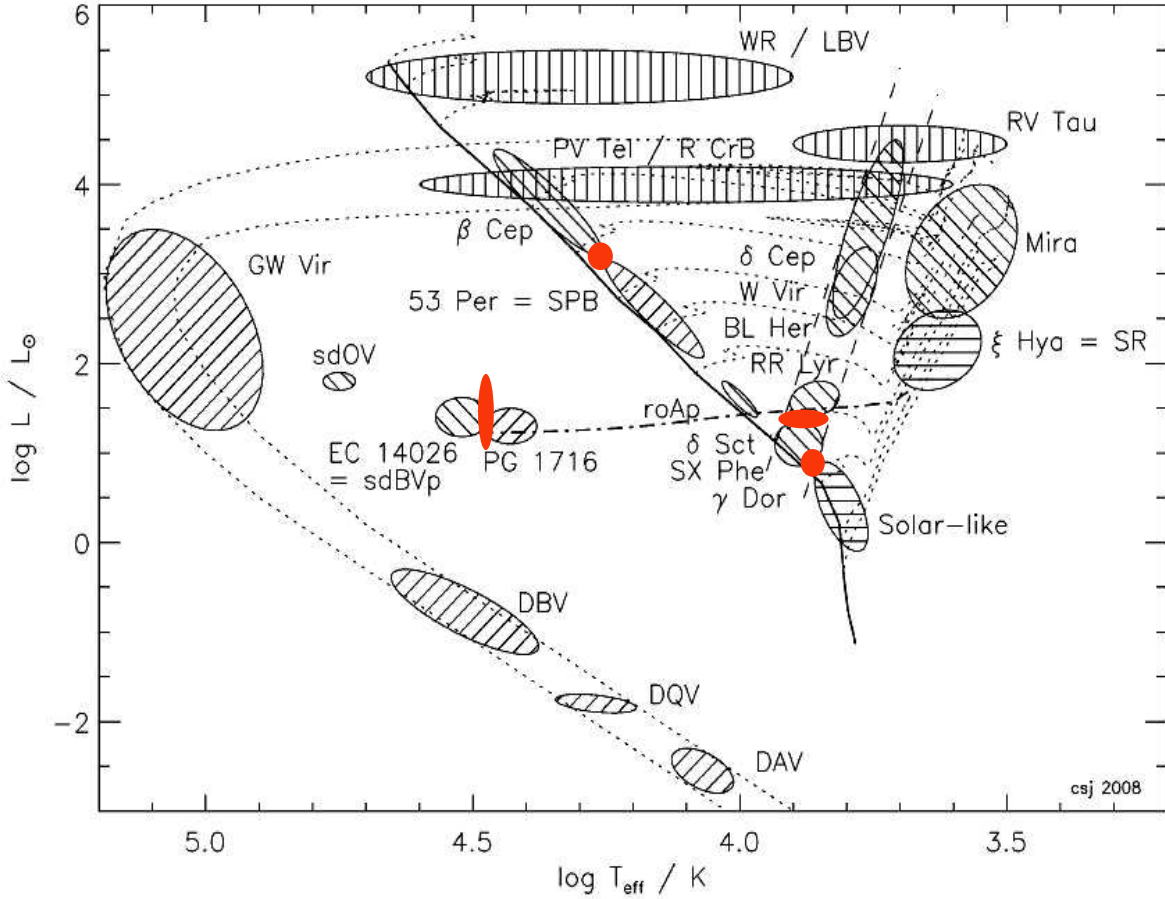


Fig. 1 A version of the Hertzsprung-Russell diagram of pulsating stars with four indicative overlapping domains. Adopted from Jeffery (2008).

than those pulsators of single types. Hybrid pulsators have excellent asteroseismic potential, as multiple types of oscillation can be exploited to obtain a more complete picture of the stellar interior (Handler 2009). A significant implication of studying hybrid pulsators is the answer why these stars present mixed pulsations. On the other hand, hybrid pulsators may lead us to better understand the underlying physical processes of stellar interior and the evolution of the stars.

We could expect that hybrid pulsators would exist in the conjunction regions of the pulsating variable stars distributed in the H-R diagram. Is the occurrence of hybrids in the H-R diagram confined to the overlapping region of two neighbouring instability domains? On the contrary, can we see an occurrence of hybrid pulsations presented in two non-adjacent classes of pulsators in the H-R diagram? In recent years, a number of hybrid pulsators have been revealed. We take three representative kinds of hybrid pulsators for examples (see Fig. 1 and Table 1).

Instability domains of δ Scuti and γ Doradus stars overlap in the H-R diagram, the existence of hybrid δ Sct – γ Dor pulsators may appear evident, and it was truly predicted by Dupret et al. (2004) and the first unambiguous detection was reported by Henry & Fekel (2005). V529 And (=HD 8801, the first single Am star pulsating with p and g modes), HD 49434 (Brunsdon et al. 2014), and TYC 3139-151-1 are three of the confirmed δ Sct – γ Dor hybrid pulsators. That means we detected both pressure- and gravity-caused non-radial pulsation in them. Moreover, γ Dor variability was also detected in a rapidly oscillating [peculiar] A-type star (roAp), and solar-like oscillations were discovered in a δ Sct star. Handler (2012) presented a review on the hybrid pulsators among A/F-type stars. KIC 3858884 is a hybrid δ Sct pulsator in a highly eccentric eclipsing binary (Maceroni et al.

2014), in which the pulsating second component showed high-order g -modes apart from the typical δ Sct pulsation frequencies of the primary component. Such a system of eclipsing binaries containing non-radial pulsators allows combining two different and independent sources of information on the internal structure and evolutionary status of the components and, at the same time, studying the effects of tidal forces on pulsations. There are many hybrid δ Sct– γ Dor pulsators (see a recent investigation by Hareter 2013).

Six slowly pulsating B stars (SPB, main-sequence stars of spectral types B2 to B9) had been found to exhibit both SPB (high-order gravity modes) and β Cephei-type (low-order acoustic and gravity modes) variability:

ν Eridani (=HD 29248, Handler et al. 2004, Dziembowski & Pamyatnykh 2008, Daszyńska-Daszkiewicz & Walczak 2010), ι Herculis (=HR 6588=HD 160762, BCEP), γ Pegasi (also a binary system, Chapellier et al. 2006, Pandey et al. 2011), 53 Arietis, V354 Persei(=HD 13745), 53 Piscium (Le Contel et al. 2001), and 12 Lacertae (Handler et al. 2006, Dziembowski & Pamyatnykh 2008). As a result of our survey, there are 20 β Cep–SPB hybrid pulsators. It is interesting to examine whether the presentation of both high-order g modes and low-order p and g modes property is consistent with the theoretical expectations.

Hybrid pulsating subdwarf B stars (sdBV) have been revealed. In fact, these hybrid sdBV pulsators showing both pressure and gravity modes form a subclass of sdBV, i.e. sdBV_{rs}. For instance, the prototype, HS 0702+6043 (=DW Lyn, Schuh et al. 2006, Lutz et al. 2008), Balloon 090100001 (Baran et al. 2005), HS 2201+2610 (=V391 Peg, Lutz et al. 2008). In addition to the hybrid pulsational behaviour, HS 2201+2610 is also a pulsator hosting an orbiting planet (Silvotti et al. 2007, Lutz et al. 2008). J08069+1527 is a newly discovered high-amplitude, hybrid subdwarf B pulsator (Baran et al. 2011).

The goal of this survey is to have an overall view of various hybrid pulsators including the three classes mentioned above. In fact, almost all stars with multiple object types are surveyed, such as stars like HD 25558, a long-period double-lined binary with two SPB components (Sódor et al. 2014), other pulsating stars in binary systems, and so on. We first extracted the information based on the Simbad database. This report presents our preliminary results, the cross table Table 2. In the next step, we plan to update the table by checking literature and other database. In the mean time, we are going to do observations on some of the interesting hybrid pulsators, especially the pulsators hosting a transiting exoplanet.

2 STATISTICS OF HYBRID PULSATING VARIABLE STARS

As Simbad provides the largest cross-identifications of all kinds of celestial objects (up to 7,709,060 by 2014 December 30), covering various surveys and published catalogs, we extract the objects with multiple identities by setting a criteria of dual object types. We must point out that the presented results in the cross table Table 2 is based solely on the Simbad database. Although Simbad archives data from 13187+ published catalogs, it certainly has a lag in updating data because it does not reflect the latest status of publications in terms of a simple literature search on ADS, as demonstrated in Table 1.

Moreover, Simbad does not check the reality of a star's multiple identities. Therefore, bias and even misclassification can be seen. For example, the δ Scuti star V577 Oph was classified as RR Lyr-type; the roAp prototype HD 101065(=V816 Cen) was not grouped in roAp stars but misclassified as a δ Sct star; the SPB prototype 53 Persei (=V469 Per) was misclassified as β Cep type (indicating mixture or confusion between β Cep and SPB sometimes), the SPB star FR Sct was misclassified to be an symbiotic star; the semi-regular prototype ξ Hya was classified as a non-variable, high proper-motion star, rather than its true type; and so on. Obviously, there are objects with confusion classifications. On the other hand, roAp stars, SPB, sdBV, α Cyg-type pulsators, and others were not explicitly classified, instead Simbad gathered them in the group '[pulsating] variable stars'. For instance,

Table 1 Samples of Representative Hybrid Pulsators.

Families of Hybrids	Hybrid Pulsators	References
β Cep–SPB hybrids	ν Eridani = HD 29248	Handler et al.(2004), Daszyńska-Daszkiewicz & Walczak(2010)
β Cep–SPB hybrids	γ Pegasi	a binary system, Chapellier et al.(2006), Pandey et al.(2011)
β Cep–SPB hybrids	ι Herculis	=HR 6588=HD 160762, B CEP,
β Cep–SPB hybrids	53 Piscium	Le Contel et al. (2001)
β Cep–SPB hybrids	12 Lac	Handler et al. (2006), Dziembowski & Pamyatnykh (2008)
hybrid δ Sct– γ Dor	V529 And	=HD 8801, 1 of the two identified by Simbad, Handler (2009)
hybrid δ Sct– γ Dor	TYC 3139-151-1	=KIC 4749989, 1 of the two identified by Simbad
hybrid δ Sct– γ Dor	BD+18 4914	by MOST, Rowe et al. (2006)
hybrid δ Sct– γ Dor	HD 114839	by MOST, King et al. (2006), Hareter et al. (2011)
hybrid δ Sct– γ Dor	CoRoT 102699796	first metal-poor Herbig Ae pulsator (Ripepi et al. 2011)
hybrid δ Sct– γ Dor	CoRoT 105733033	Chapellier et al. 2012
hybrid δ Sct– γ Dor	CoRoT 100866999	in EB, Chapellier & Mathias (2013)
hybrid δ Sct– γ Dor	HD 49434	Brunsdan et al. (2014)
hybrid δ Sct– γ Dor	KIC 6761539	Herzberg et al. (2012)
hybrid δ Sct– γ Dor	KIC 8569819	in EA, Kurtz et al. (2015)
hybrid sdBV: sdBV _{rs}	HS0702+6043	=DW Lyn, the prototype, Schuh et al.(2006), Lutz et al.(2008)
hybrid sdBV: sdBV _{rs}	Balloon 090100001	Baran et al. (2005)
hybrid sdBV: sdBV _{rs}	HS 2201+2610	=V391 Peg, planet-hosting sdBV, Lutz et al.(2008)
hybrid sdBV: sdBV _{rs}	RAT0455+1305	Baran & Fox-Machado (2009)
hybrid sdBV: sdBV _{rs}	J08069+1527	Baran et al. (2011)
hybrid PG 1159	HS 2324+3944	=V409 And, DOV, pulsating pre-white dwarf, Handler et al.(1997)
hybrid PG 1159	Abell 43	Vauclair et al. (2005)
hybrid B-type pulsator	HD 25558	=V1133 Tau, double-lined binary of SPB+SPB components

the long-period (slow) g -mode sdBVs PG 1716+426 (=V1093 Her) was listed to be a spectroscopic binary as main object type together with the white dwarf type. So we are unable to extract directly the stars belonging to several specified classes, including sdBV¹, SPB, α Cyg-type pulsating stars, etc.

Simbad currently resolved only two δ Sct– γ Dor hybrid pulsators (V529 And, TYC 3139-151-1), but actually more than ten such stars are identified in the literature (see Table 1). One can make a hypothesis that all objects in the overlapping region between p - and g -modes are hybrid stars. In their close vicinity there are two other stars with only p -modes whileas a bunch of stars with only g -modes detected (refers to fig.8 of Baran & Fox-Machado 2009). Based on the CoRoT LRA01 light curves, there are 418 γ Dor candidates, 274 δ Sct– γ Dor hybrid candidates were resolved (see p.18 of Hareter 2013). While the Kepler mission reports a large sample of γ Dor stars (Tkachenko et al. 2013).

As such, the numbers of each kind of pulsating stars as well as the statistics of hybrid pulsational behaviour are not by no means indisputable. Missing of member stars in a class of pulsators as well as discrepancies between the Simbad data and other existing catalogs or database (e.g, ADS, CoRoT, Kepler data archives, etc.) are common. Taking the above into consideration, one needs to re-check the Simbad and other database for an update before using the data. In this regard, a web-based version of the present cross table (Table 2) has been developed at

¹ Actually we retrieved the Simbad by spectral type 'sdB' together with object type 'V*' for sdBV.

<http://www.chjaa.org/COB/hybrid/>², which aims at providing the latest status of hybrid variability types. Future updates will be first made available on the web.

In addition, we performed a relevant statistics on the major types of variable stars. As of 2014 December 31, Simbad has archived 7709060 objects — this number changes daily, of which 3754965 and 248103 are stars and variable stars, respectively, the rest are non-stellar objects (galaxies, planetary nebulae, etc.). GCVS4.2 collected 58947 designated known variables (including 10979 extragalactic variables, Samus et al. 2012), which accounts for only 23.7% of the Simbad’s variables. The detailed percentages of each class of variables in the whole database are given in Table 4. Some interesting hybrid pulsators are collected in Table 5, where the reality of multiple identities was not examined one by one. Because the leading columns of Tables 2–5 are the Simbad’s acronyms, which are not widely used by astronomers, a lookup table (Table 6) for the acronyms is provided. This table also lists the numbers of stars in each class.

In both theoretical and observational points of view, we would draw the readers’ attention towards the followings:

- (1) Pay close attention to the zero occurrences of any combinations of different types of pulsators in Table 2, especially those overlapped or adjacent regions on the H-R diagram
- (2) There are actually multiple identities for the hybrid pulsators, check the details for any one hybrid.
- (3) Close attention should be also paid to the binary systems containing pulsating stars. There are quite a number of EB, SB, ELL, and multiple-star systems containing pulsating component[s]. We refer readers to Zhou (2010) for further information.
- (4) Observers are encouraged to look at the ‘EP’ entry — the planetary transit systems. More efforts are deserved to searching for various possible pulsators containing exoplanets. By now, at least two sdBV stars are known to have planets: V391 Pegasi was the first known sdB planet-host, and Kepler-70 has a system of close-orbiting planets that may be the remnants of a giant planet that was engulfed by the red giant progenitor.

3 ASTROPHYSICAL IMPLICATIONS AND OPEN QUESTIONS

Apart from enhancing observational efforts in hybrid pulsators, we address the theoretic studies on the excitation of different types of pulsational modes in hybrid pulsators. Several attempts are found for reference:

- (i) Can opacity changes help to reproduce the hybrid star pulsations in β Cep–SPB dual pulsators (Zdravkov & Pamyatnykh 2008)? From a theoretical point of view, Pamyatnykh (1999) and Miglio et al.(2007) showed that with OP opacities (Seaton 2005), the instability strips of β Cep and SPBs intersect, so that theoretical models with both unstable p -modes and high order g -modes exist.
- (ii) Improvements in current models for hybrid sdBV, e.g. the driving mechanism for long-period, high-order g -modes in long-period pulsating subdwarf B stars, given by Fontaine et al.(2003).
- (iii) Driving and damping mechanisms in hybrid pressure–gravity modes pulsators (Dupret et al. 2009): γ Dor instability strip overlaps the red edge of the δ Sct. γ Dor are stars pulsating with high order g -modes, apart from white dwarfs and slowly pulsating B (SPB) stars. For the hybrid γ Dor– δ Sct stars, a comparison between observation and theory was done by Bouabid et al.(2009). Using non-adiabatic computations, they predict the excitation of both γ Dor and δ Sct modes separated by a region of stable modes in models located

² The web page in fact provides a friendly accessing interface to the Simbad database in such a way that one can enquiry any kind of hybrids among various variable stars. The output format of the resulting page was initialized through a script acting the similar function of the Simbad’s ‘Output options’ settings. So one can re-configure the ‘Output options’ to view more parameters.

in the region of the H-R diagram where hybrid candidates have been detected. The hybrid stars occupy the same area with δ Sct stars and is not confined to the overlapping region in the H-R diagram. They behave differently in the g -mode regime from γ Dor stars. They likely form a different class of pulsating stars and are not merely a simple mixture of δ Sct and γ Dor types pulsations. Thus a different driving mechanism is demanded to excite the observed g -modes of hybrid stars. A detailed discussion on δ Sct– γ Dor hybrids can be found in Grigahcène et al.(2010) and Hareter (2013).

- (iv) Modified modelling is demanded to explain the existence of hybrid pulsations. Attempts towards seismic modelling of the observed hybrid pulsation frequencies, for the β Cep–SPB, δ Sct– γ Dor, and sdBV_{rs} are overwhelming.

4 ENDING REMARKS

The goal of this survey is to have an overall view of various hybrid pulsators, actually the variables with multiple variability types. We have extracted the hybrid information based on the [Simbad](#) astronomical database. This report presents our preliminary results, the cross table Table 2 along with several related statistics (Tables 3–4). A web page (<http://www.chjaa.org/COB/hybrid/>) that allows one to retrieve the hybrid stars of any two types of variability is developed. We draw the readers' attention to several kinds of hybrid pulsators, including pulsating stars in binary systems, pulsating stars hosting transiting exoplanets, and so on. In the next step, we plan to update the table by checking literature and other database. In the mean time, we are going to do observations on some of the interesting hybrid pulsators.

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Table 2 A Statistics on the Multiple Identities Hybrid Pulsating Variable Stars[†].

	BCEP	DCEP	CEP	CV	DSCT	GDOR	M	roAp	RR	RV	sdBV	SR	SXPHE	WR	CW	ZZ	WD	HB	BS
	bC*	cC*	Ce*	CV*	dS*	gD*	Mi*	a2*	RR*	RV*	sdB	sr*	SX*	WR*	WV*	ZZ*	WD*	HB*	BS*
bC*	332	0	1	0	1	0	0	0	0	0	5	0	0	1	0	0	1	6	0
cC*	0	4432	1970	2	2	1	0	0	42	2	0	2	18	0	6	0	1	1	0
Ce*	1	1970	13710	2	1	0	2	0	31	17	1	5	0	0	123	0	0	0	0
CV*	0	2	2	1060	1	0	1	0	0	0	1	2	0	0	0	5	29	0	0
dS*	1	2	1	1	5197	2	0	0	46	0	0	0	9	0	0	0	1	14	1
gD*	0	1	0	0	2	717	0	2	1	0	0	0	0	0	0	0	0	0	1
Mi*	0	0	2	1	0	0	10837	0	3	0	0	112	0	0	0	0	1	0	0
a2*	0	0	0	0	0	2	0	515	0	0	0	0	0	0	0	0	0	0	0
RR*	0	42	31	0	46	1	3	0	62319	1	0	14	39	0	22	0	0	144	16
RV*	0	2	17	0	0	0	0	0	1	262	0	13	0	0	8	0	0	0	0
sdBV	5	0	1	1	0	0	0	0	0	0	57	0	0	0	0	1	3	13	0
sr*	0	2	5	2	0	0	112	0	14	13	0	20110	0	1	2	0	0	0	0
SX*	0	18	0	0	9	0	0	0	39	0	0	0	447	0	0	0	1	1	22
WR*	1	0	0	0	0	0	0	0	0	0	0	1	0	1407	0	0	0	0	0
WV*	0	6	123	0	0	0	0	0	22	8	0	2	0	0	749	0	0	0	0
ZZ*	0	0	0	5	0	0	0	0	0	0	1	0	0	0	0	220	185	2	0
AB*	0	0	2	0	1	0	0	0	0	4	0	699	0	0	0	0	0	0	0
pA*	0	0	6	0	0	0	2	0	1	94	0	39	0	1	1	1	3	0	0
RC*	0	0	0	0	0	0	6	0	0	0	0	25	0	0	0	0	0	0	0
s*b	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0		0	0	0
Pu*	12	4	7	2	46	19	5	2	7	13	57	142	2	0	21	4	5	14	0
blu	3	0	1	17	8	0	0	7	11	0	2	1	0	0	0	16	927	134	10
BS*	0	0	0	0	1	1	0	0	16	0	0	0	22	0	0	0	48	351	4024
HB*	6	1	0	0	14	0	0	0	144	0	13	0	1	0	0	2	61	18633	351
sdB	10	0	1	1	0	0	0	0	0	0	1120	0	0	0	0	1	161	49	0
WD*	1	1	0	29	1	0	1	0	0	0	3	0	1	0	0	185	20567	61	48
El*	3	4	8	0	13	9	0	1	0	1	1	1	0	3	2	0	0	1	0
Al*	0	2	1	12	4	8	0	0	9	0	0	3	1	5	1	0	5	0	0
bL*	0	1	4	1	3	1	0	0	1	0	1	0	0	3	0	0	0	0	0
BY*	0	0	0	1	0	1	0	0	0	0	0	1	0	0	0	0	2	0	0
EB*	2	16	43	4	22	23	2	0	35	7	4	12	4	4	13	0	20	2	7
SB*	14	42	21	24	36	13	1	35	26	0	3	26	3	47	2	0	1007	51	4
EP*	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
WU*	3	2	5	1	12	3	0	0	43	0	0	1	0	0	0	0	1	1	2
RS*	0	20	19	0	0	0	0	0	1	0	0	2	0	0	1	0	3	0	0

[†]Note: Check the latest updates via the web version at <http://www.chjaa.org/COB/hybrid/>.

Table 3 Multiple Identities Hybrids: the Intrinsic Pulsating Variable Stars in Binary Systems and others.

	EA	BCEP	BY	EP	RS	EW	Be			ELL	Em	UV	post-AGB
	Al*	bL*	BY*	EP*	RS*	WU*	Be*	pr*	blu	El*	Em*	UV	pA*
bC*	0	0	0	0	0	3	12	0	3	3	20	174	0
cC*	2	1	0	0	20	2	0	4	0	4	0	21	0
Ce*	1	4	0	0	19	6	0	2	1	8	19	19	6
CV*	12	1	1	0	0	1	0	0	17	0	13	81	0
dS*	4	3	0	0	0	12	0	1	8	13	3	310	0
gD*	8	1	1	0	0	3	0	0	0	9	2	72	0
Mi*	0	0	0	0	0	0	0	1	0	0	188	1	2
a2*	0	0	0	0	0	0	0	0	7	1	1	357	0
RR*	9	1	0	0	1	43	0	2	11	0	5	49	1
RV*	0	0	0	0	0	0	0	1	0	1	10	1	94
sdBV	5	1	0	0	0	0	0	0	2	1	0	15	0
sr*	3	0	1	0	2	1	0	2	1	1	120	21	39
SX*	1	0	0	0	0	0	0	0	0	0	0	1	0
WR*	5	3	0	0	0	0	2	0	0	3	261	75	1
WV*	1	0	0	0	1	0	0	0	0	2	0	0	1
ZZ*	0	0	0	0	0	0	0	0	16	0	4	68	1
AB*	0	0	0	0	0	0	0	0	0	0	8	1	12
Al*	6634	72	1	0	10	37	2	39	7	2	48	377	0
bL*	72	1590	0	0	1	46	6	19	0	3	36	199	1
blu	7	0	0	0	1	0	7	0	19335	2	11	2019	9
BS*	0	0	0	0	0	2	0	0	10	0	0	7	0
BY*	1	0	978	0	3	0	0	63	0	0	40	104	0
EB*	1189	193	3	1	5	618	5	22	0	113	36	141	0
El*	2	3	0	0	1	8	3	0	2	501	13	95	0
EP*	0	0	0	31	0	0	0	0	0	0	0	0	0
HB*	0	0	0	0	0	1	0	0	134	1	0	90	0
pA*	0	1	0	0	0	1	3	1	9	0	39	24	454
Pu*	5	3	2	0	1	7	19	4	5	30	126	299	22
RC*	1	0	0	0	0	0	0	0	0	0	2	1	35
RS*	10	1	3	0	511	5	0	8	1	1	10	94	0
s*b	1	4	0	0	0	0	0	0	3	3	78	155	1
SB*	329	136	35	2	184	153	31	43	131	68	232	1468	4
sdB	5	1	0	0	0	0	0	0	100	2	0	398	0
WD*	5	0	2	0	3	1	0	1	927	0	9	1834	3
WU*	37	46	0	0	5	5064	0	24	0	8	1	43	1

Table 4 A Statistics on the Major Types of Stars Archived by Simbad. Third and Fourth Columns Refer to the Ratios to All Variables and to All Stars, Respectively.

Type of Pulsators (Simbad's ID)	Numbers	Percentage (1/100)	Ten-Thousandth (1/10000)	Type of Pulsators (Generic Names)
RR*	62319	25.12	165.96	RR Lyr-type stars
WD*	20567	8.29	54.77	White Dwarfs
sr*	20110	8.11	53.55	semiregular variables
blu	19335	7.79	51.49	blue objects
EB*	19234	7.75	51.22	Eclipsing Binaries
HB*	18633	7.51	49.62	Horizontal Branch stars
Ce*	13710	5.52	36.51	Cepheids
Mi*	10837	4.36	28.86	Mira-type
Pu*	7738	3.12	20.61	Pulsating variable stars
SB*	6985	2.81	18.60	Spectroscopic Binaries
Al*	6634	2.67	17.67	Algol-type EB
dS*	5197	2.09	13.84	δ Scuti stars
WU*	5064	2.04	13.48	W UMa-type EB
AB*	4435	1.79	11.81	Asymptotic Giant Branch stars
cC*	4432	1.79	11.80	classical Cepheids
BS*	4024	1.62	10.71	Blue Straggler stars
bL*	1590	0.64	4.23	β Lyr-type
WR*	1407	0.57	3.75	Wolf-Rayet stars
sdB	1120	0.45	2.98	subdwarf B stars
CV*	1060	0.43	2.82	Cataclysmic Variables
BY*	978	0.39	2.60	BY Dra-type
WV*	749	0.30	1.99	W Vir-type
gD*	717	0.28	1.90	γ Dor stars
s*b	542	0.22	1.44	luminous blue variables
a2*	515	0.21	1.37	α^2 CVn, roAp
RS*	511	0.20	1.36	RS CVn-type
El*	501	0.20	1.33	ellipsoidal variables
pA*	453	0.18	1.20	post AGB
SX*	447	0.18	1.19	SX Phe-type
bC*	332	0.13	0.88	β Cep-type
RV*	262	0.11	0.69	RV Tau-type
ZZ*	220	0.09	0.58	ZZ Cet type
RC*	150	0.06	0.39	R CrB-type
sdBV	57	0.02	0.15	pulsating sdB
EP*	31	0.01	0.08	eclipses by planet
**	97421	2.59		double/multiple stars vs all stars
V*	248103	6.61		all variables in stars as of Dec.31, 2014
*	3754965	—		all stars as of Dec.31, 2014
GCVS4.2	58947	23.7		GCVS' total variables vs the Simbad's

Table 5: Selected Interesting Hybrid Pulsators with Dual or Multiple Identities. The Reality of Multiple Identities Are Not Examined. Check the Entries at: <http://www.chjaa.org/COB/hybrid/>.

Hybrid Identities [†]	N	Notes
a2+Em+UV	1	V1045 Ori=HD 36916
AB+pA+UV	1	NGC 5904 MSB 1, AB=Asymptotic Giant Branch Star (AGB)
Al+SX	1	KIC 10989032: SX Phe-type star in Algol-type EB
bC+Ce+UV	1	V757 Per
bC+El+HB+Pu+sdB	1	2MASS J19343993+4758117
bC+Em+WR	1	V1035 Sco
bC+HB+El	1	2MASS J19343993+4758117
bC+UV+WD	1	1am Sco
bL+CV	1	KIC 5112741
bL+pA	1	HP Lyr, EB of β Lyr-type, semi-detached
BS+gD	1	KIC 5024455
BY+CV	1	NGC104 EGG V27
cC+**	30	cC in double/multiple stellar systems
cC+bL+Ce	1	V480 Lyr
cC+Ce	1970	cC=classical Cepheids= δ Cep type (DCEP)
cC+Ce+RR	9	Ce=Cepheids, RR=RR Lyr-type
Ce+Al	1	KIC 2447893, EA+Ce
Ce+blu	1	TYC 656-628-1
Ce+RR	31	Ce*=Cepheids
CV+AM+sr+PM+blu+UV	1	AR UMa: (CV of AM Her type, polar)
dS+AB	1	V5505 Sgr, δ Sct star
dS+bC	1	V1228 Cen=HD 100495
dS+blu+UV	2	ER Leo, DT CVn
dS+BS+blu	1	PHL 319
dS+BS+HB	1	SDSS J022422.40+004500.8
dS+Ce	1	KIC 9594189:
dS+CV	1	V1209 Tau
dS+pr	1	V1247 Ori
dS+RR	46	1 SB, e.g. UY Cam, SZ Lyn, AD CMi, VZ Cnc, BS Aqr . . .
dS+RR+UV	4	UV=Eruptive variables of the UV Ceti type
dS+SX	9	1 EB; BQ Psc: SX+HB+dS+cC
dS+WD+SB+UV	1	IK Peg
El+a2+SB+UV	1	33 Tau (=V817 Tau =HD 24769)
El+RS+UV+SB	1	ι Tri
El+SB+Pu	1	HY Vel

Continued on next page

Table 5 – continued from previous page

Hybrid Identities [†]	N	Notes
gD+bL	1	2MASS J18441225+0613529
gD+BY	1	FG CVn
gD+cC	1	2MASS J06522020-0535137
Mi+CV	1	FQ Mon
Mi+pr	1	HV 1644, Mira Cet type
Mi+WD+PM+Em+UV+Mas	1	omi Cet, Mira Cet type
pA+Em+WR	1	OH 284.2 -0.8, post-AGB star
Pu+SB+CV	1	4 Dra
RC+Al	1	V532 Oph, R CrB type
RC+pA+Em+UV	1	R CrB, R CrB type
RR+bL	1	TZ Cap
RR+gD	1	2MASS J06520507-0511481=CoRoT 110679591
RR+SX	39	e.g. XX Cyg, AE UMa, CY Aqr, DY Peg
RR+SX+cC	7	e.g. XX Cyg, V1638 Oph, V879 Her
RS+bL+Em+pr	1	FI Cru
RS+blu+SB	1	EZ Peg
RS+Pu+SB	1	BM Lyn
RS+RR+SB	1	AG Cnc
RS+SB+blu	1	EZ Peg
RV+El+Ce	1	HV 1369
RV+pA+UV	1	AC Her
RV+RR	1	V1127 Aql
sdb+Pu+ZZ+HB	1	2MASS J19090714+3756143
sdBV+EB+bL+Ce	1	TYC 3556-3568-1
sdBV+EB+CV+Pu	1	NAME KBS 13
sr+BY	1	GQ Vel
sr+El	1	V5485 Sgr: semi-regular pulsating star
sr+pr+RV+pA	1	UY CMa: semi-regular pulsating star
sr+WR+pA?+Mas	1	PZ Cas: double stars
sr+WU	1	V2616 Oph
SX+dS+HB+cC	1	BQ Psc
SX+WD+cC	1	BL Cam
WD+pr+UV+SB	1	HD 217411
WU+bL+dS	1	FH Cam
WU+CV	1	NGC 104 EGG V7
WU+dS+bL+UV	1	CC Lyn
WU+Em+pr	1	V1537 Ori
WU+HB	1	BD Gru

Continued on next page

Table 5 – continued from previous page

Hybrid Identities [†]	N	Notes
WU+pA+RR	1	V1017 Cyg, EB of W UMa type, contact
WU+WD+UV	1	NGC 104 EGG V20
WV+AI	1	V538 Ara
WV+pA	1	ST Pup
WV+RR+Ce	3	WV=variables of W Vir type
WV+RS	1	MX Dra
ZZ+pA	1	LW Lib, Pulsating White Dwarf

The end of Table 5

Table 6 Lookup Table of the Surveyed Pulsators: the Simbad Object Types against GCVS Acronyms.

Simbad	GCVS	Numbers	Extended explanation
1. Pulsating Variables			
—	ACYG	64	α Cygni-type non-radial pulsating supergiant stars of spectral types B or A
bC*	BCEP	332	Pulsating Variable Star of β Cephei-type, multiperiodic
bL*	EB(b)	1590	Eclipsing binary of β Lyr type (semi-detached)
BS*	BSS	4024	Blue Straggler Stars: main-sequence stars in open/globular clusters that are more luminous and bluer than stars at the MS turn-off point for the cluster.
cC*	DCEP	4432	classical Cepheids (i.e. δ Cephei-type variables, pop. I, luminous, massive)
Ce*	CEP	13710	Cepheids, variable stars of radially pulsating, high luminosity
DQ*	—	40	CV DQ Her type (intermediate polar), e.g. FO Aqr, XY Ari, V667 Pup, PQ Gem
dS*	DSCT	5197	Pulsating Variable Star of δ Scuti-type, radial, nonradial, pressure modes
gD*	GDOR	717	Pulsating Variable Star of γ Doradus-type, gravity modes
HB*	HB	18633	Horizontal Branch (HB) stars: at a stage of stellar evolution that immediately follows RGB
sdB	sdB/sdO/RPHS	57	sdBV/sdOV: pulsating subdwarf B/O variable stars: very hot and bright subdwarf stars (core helium burning, $T_{\text{eff}} \sim 20,000\text{--}40,000$ K, $\log g \sim 5.0\text{--}6.2$, $M \sim 0.5 M_{\odot}$) with spectral type B or O, situated at the extreme/hottest horizontal branch of the H-R diagram unlike normal horizontal branch stars (Herber 2008, 1986). Three sub-types: (1) short-period(rapid) p -mode: sdBVr: $P=90\text{--}600$ s, prototype EC 14026=V361 Hya: PG 1605+072, PG 1047+003, PG 0014+067; (2) long-period(slow) g -mode: sdBVs (or LPsdBV), $P=45\text{--}180$ m, PG 1716+426=V1093 Her; (3) hybrid p - and g -mode: sdBVrs, DW Lyn=HS 0702+6043.
blu	—	19335	blue (horizontal branch) objects
LPB	LPB	—	Long-period pulsating B stars ($P > 1$ d)
Mi*	M	10837	Mira (Omicron Cet): Variable Star of Mira Cet type
—	PVTEL	—	PV Telescopii-type pulsators
Pu*	—	7738	Pulsating variable Star
RR*	RR	62319	RRab/RRc/RRd: RR Lyr variables: radially-pulsating, old Pop.II giant in globular clusters
RV*	RV	262	type-II Cepheids of RV Tauri-type: radially pulsating yellow supergiants,
WV*	CW	749	CWA, CWB: type-II Cepheids of W Virginis-type, BL Her-type
sr*	SR	20110	Semiregular pulsating variables: sub-types: SRA,SRB,SRC,SRD
SX*	SXPHE	447	SX Phe-type variables: pulsating subdwarfs, old disk galactic Pop. in globular clusters
ZZ*	DAV,DBV,DOV	220	pulsating white dwarfs of ZZ Ceti type: ZZA, ZZB
—	SPB	—	slowly pulsating B star(SPB), prototype 53 Persei: main-sequence stars of spectral types B2 to B9, 6 had been found to exhibit both SPB+ beta Cephei variability.
a2*	roAp	515	Variable Stars of Alpha ² CVn-type (or α^2 CVn variable): chemically peculiar main-sequence stars of spectral class B8p to A7p. They have strong magnetic fields and strong silicon, strontium, or chromium spectral lines. The chemically peculiar roAp (rapidly oscillating A-type peculiar stars, or Przybylski's stars) occupy the MS end of the δ Sct instability strip.

Table 6 — Continued

Simbad	GCVS	Numbers	Extended explanation
2. Eruptive variables:			
RS*	RS	511	Eruptive variables of the RS CVn type: Close binaries with chromospheric activity, causing very small light variations. Eclipses and X-ray variability often seen as well.
s*b	LBV/SDOR	542	Luminous Blue Variables (LBVs): massive evolved, very luminous blue supergiant stars, usually surrounded by expanding envelopes known as S Doradus-type variables: unpredictable, dramatic variations in both spectra and brightness, often associated with nebulae. Occasional outbursts up to 7 magnitudes, lasting for months, caused by ejection of a shell of matter, e.g. P Cyg, η Carinae, AG Car, AE And, AF And.
UV	UV	91387	Eruptive variables of the UV Ceti type, UV-emission source, red dwarf stars showing outbursts up to 6 magnitudes lasting for only a few minutes, caused by flares.
WR*	WR	1407	Systems having Eruptive Wolf-Rayet stars. Emission lines of carbon & nitrogen and evidence for unstable mass outflow as a “stellar wind”.
RC*	RCB	150	pulsating variables of the R CrB type: hydrogen-poor, carbon- and helium-rich, high-luminosity stars, simultaneously eruptive and pulsating variables
Em*	Em	21353	Emission-line stars
Er*	Er	68	Eruptive variable Star
FU*	FU	40	Variable Star of FU Ori type
LP*	LPV	76895	Long-period variable star, e.g. FZ Cas, V475 Cyg, CI Cas.
3. Eclipsing Binary Systems			
AI*	EA	6634	Algol-type eclipsing binary systems (detached), EB of Algol (β Persei),
EB*	E	19234	Eclipsing binary systems
bL*	EB(b)	1590	β Lyrae-type eclipsing binary systems, having ellipsoidal components
WU*	EW	5064	W Ursae Majoris-type eclipsing binaries (contact).
EP*	—	31	Star showing eclipses by its planet – planetary transit
RS*	RS	511	Variable of RS CVn type, close binary, non-pulsation, starspots-caused variability
SB*	SB	6985	Spectroscopic binary
WD*	WD	20567	WDA, WDB: Systems with White-Dwarf components
XB*	XB	1422	close Binary systems showing X-ray and optical bursts.
4. Rotating variables			
BY*	BY	978	BY Draconis-type variables: non-pulsation, multiple stars, starspots-caused variability, many are UV variables
EI*	ELL	501	Rotating ellipsoidal variables: elliptical, tidally distorted, close binary stars with ellipsoidal components, no eclipses
5. Cataclysmic (Explosive and Novalike) Variables			
AB*	AGB	4435	Asymptotic Giant Branch stars: bright red giant (He-burning).
pA*	—	453	post-AGB (Asymptotic Giant Branch) stars
RG*	RGB	15437	Red Giant Branch stars
AM*	—	91	CV of AM Her type (polar), e.g. EP Dra, ES Cet, AN UMa, AR UMa, VV Pup
CV*	CV	1060	Cataclysmic Variable stars
DN*	DN	648	Dwarf Novae
SN*	SN	9066	SuperNovae
NL*	NL	110	Nova-like variables
No*	N	1788	Nova, close binary
Sy*	—	231	Symbiotic Stars
6. non-pulsating variables			
pr*		6105	Pre-main sequence stars

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